

The **Institution**
of **Structural**
Engineers

Possible solution to past CM exam question

Question 2 – July 2015

New city centre office block

by Rajavel Inbarajan

The information provided should be seen as an interpretation of the brief and a possible solution to a past question offered by an experienced engineer with knowledge of examiners' expectations (i.e. it's an individual's interpretation of the brief leading to one of a number of possible solutions rather than the definitive "correct" or "model" answer).

Question 2. New city centre office block

Client's requirements

1. A new city centre six-storey offices block with lower basement parking: see Figure Q2. The site is bounded by a public footpath on three sides and an access road at the rear. Main streets adjacent to the site are busy, and traffic flow is to be maintained during construction.
2. Two stair and lift cores extend the full height of the building. The front and concourse elevations will be fully glazed with no bracing permitted. 70% of the area of the side and rear elevations will be glazed and the remainder will be clad in stone panels.
3. Floor-to-ceiling heights in the office are to be 2.9m. A 0.55m-deep ceiling services zone is to be provided over each office floor. The maximum height of the eaves of the building above Level 1 is 27.0m. The clear storey heights in levels -1 to -3 are to be 2.25m. The structural zone for the ground floor (level 1) is 1.5m deep and for levels -1 and -2 floors it is 0.5m deep.
4. Car-parking bays are to be a minimum of 5.0m x 2.5m with aisles 6.9m wide for vehicle circulation.
5. One internal row of columns is permitted within the office floors, with columns spaced at least 7.5m apart centre-to-centre. There is no restriction on column locations in the car-park levels providing circulation is not impaired.

Imposed Loading

6. Roof	1.5kN/m ²
Office floors	5.0kN/m ²
Concourse	5.0kN/m ²
Car Park	2.5kN/m ²

Loadings exclude allowances for floor finishes, ceilings and services.

Site Conditions

7. The site is in a city centre location. Basic wind speed is 51m/s based on a 3-second gust; the equivalent mean hourly wind speed is 25.5m/s.
8. Ground Conditions

0 – 1m	Made ground
1.5 – 25m	Stiff clay C = 150kN/m ²
Below 25m	Sandstone, safe bearing pressure 2,500kN/m ²

Some ground water was encountered at 4.0m below ground level but seepage rates were low.

Omit from consideration

9. Detailed design of staircases, lifts within cores, and car park access ramps.

SECTION 1

(50 marks)

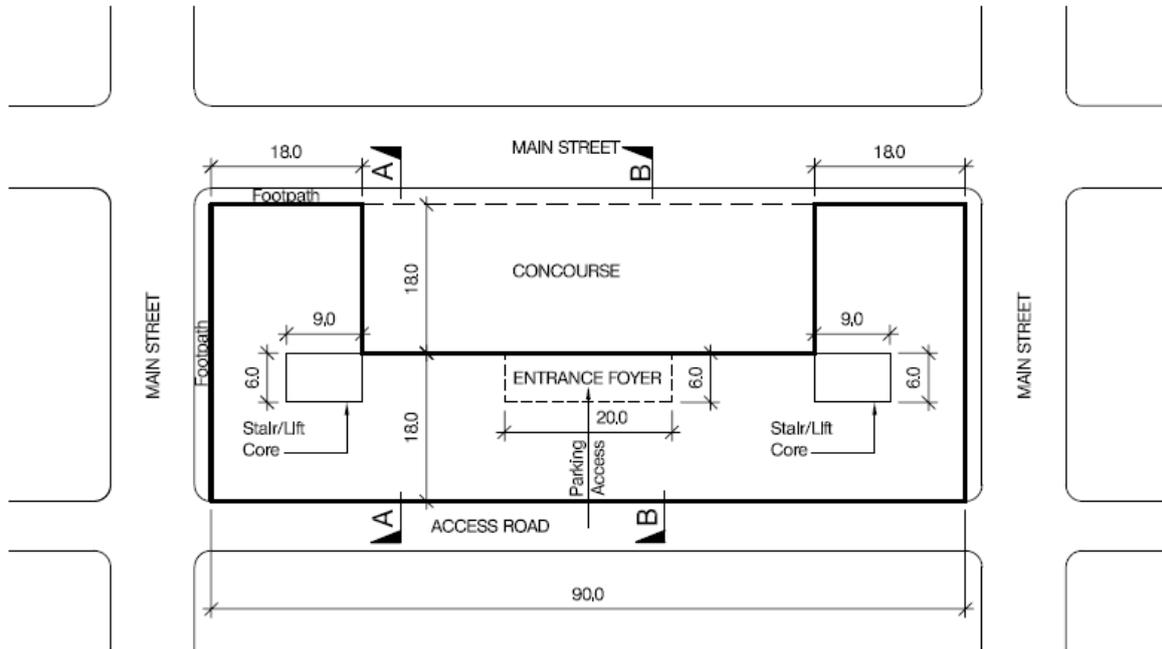
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the fundamental framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After completion of the design and before construction has started, the client advises that only one half of the building footprint is to be constructed as an initial phase. Write a letter to the client explaining the feasibility and impact of this proposal. (10 marks)

SECTION 2

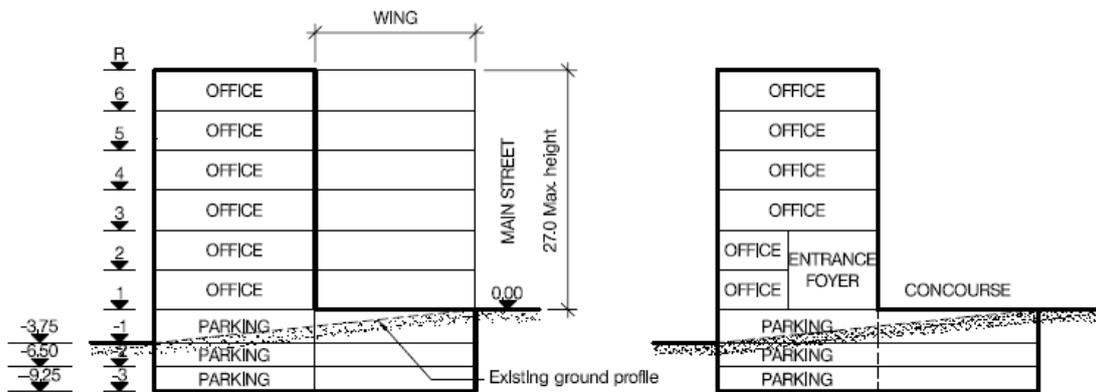
(50 marks)

For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20 marks)
- e. Prepare a detailed method statement for the safe construction of the building and an outline construction programme. (10 marks)



LEVEL 1 PLAN



SECTION A-A

SECTION B-B

NOTE: All dimensions are in metres

FIGURE Q2

Introduction

This question tests the competency of candidates in designing a six-storey new city centre offices block with lower basement parking and sloping ground across the site.

It is quite common that the Chartered Membership Examination tests candidate's competency in aspects of both geotechnical engineering and structural engineering. This question demands an understanding of various methods of retaining deep excavation works, both in temporary and permanent conditions especially with a sloping site, surrounded by busy roads, in a city centre.

Therefore, it is quite natural that the question is daunting for those candidates that lack experience in heavy geotechnical design and construction works involving deep excavations. However, it is definitely not a difficult question for engineers with experience in dealing with the design and construction of earth retaining and supporting structures and concrete/steel structures.

This possible solution is not prepared under examination conditions. It is provided to assist candidates with their preparation for the Chartered Membership Examination with respect to arriving at two distinct and viable solutions as required in Section 1(a) of the question. The annotated sketches provided were drawn on graph paper and then transferred to plain papers to improve the clarity. In the examination, candidates may use the A4 size answer sheets to draw the annotated sketches required as part of their design appraisal in Section 1(a).

Some guidance is given on the recommendation for scheme selection in Section 1(a).

It also explains the structural implications of constructing one half of the building in an initial phase of construction and gives guidance to the candidates in writing a letter to the client as required in Section 1(b).

The issues

- The site consists of **sloping ground** and is situated in a busy **city centre**.
- The footprint of the building basement is 90m x 36m.
- **No bracing** is permitted in the front and concourse elevations that are fully glazed. 70% of the side and rear elevations are glazed and the remainder is clad in stone.
- **Maximum height** of the eaves of the building above **L1** is **27.0m**.
- Only **one row of column** is permitted within the office floors. There is no restriction on column locations in the car-park levels provided circulation is not hindered.

The following is worth noting.

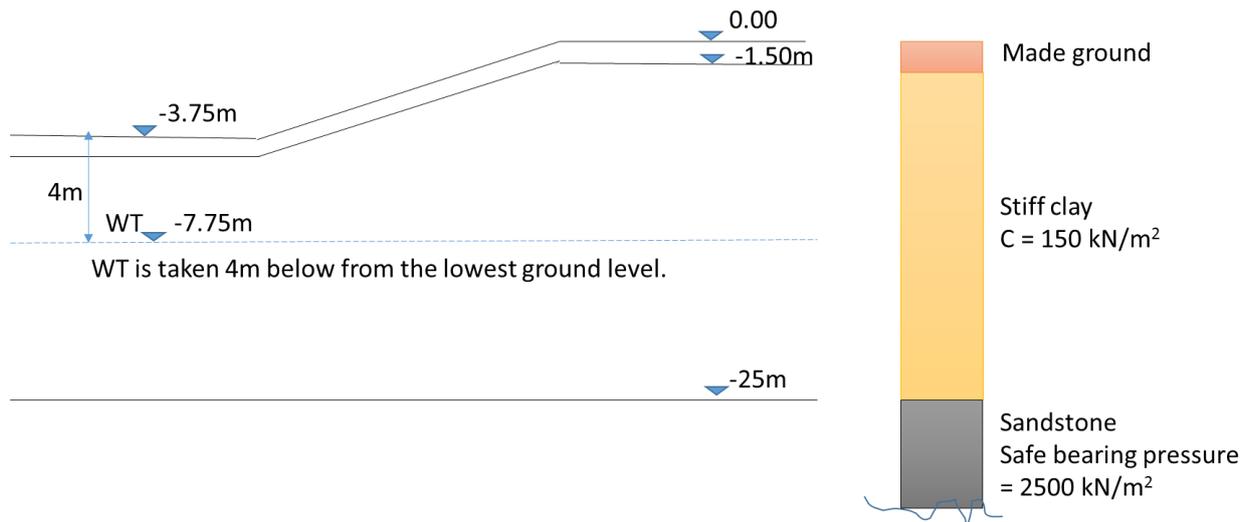
Site boundary

It is expected that the candidate should appreciate the fact that the site is situated in the city centre and surrounded by busy roads. As such the working space available outside the footprint of the building is limited. Hence, it is important to consider this constraint in the systems selected for earth retaining, supporting structures and building foundations in order not to consume more space outside the footprint of the building during construction.

Site conditions

Wind data is provided in terms of a basic wind speed (51m/s) with a 3 second gust and equivalent mean hourly wind speed (25.5m/s). The candidate has the liberty to choose the basic wind speed or mean hourly wind speed values given in the question based on their local practice as its varies from country to country.

Ground conditions varies as follows;



The geotechnical design parameters should be worked out from the given ground conditions.

- The question states that some ground water was encountered 4.00m below ground level with low seepage rate. The ground water level has been taken as shown above.
- Density of the made ground could be taken as 19 kN/m^3 .
- Active earth pressure coefficient (K_a) and earth pressure coefficient at rest (K_0) can be calculated based on the $C=150 \text{ kN/m}^2$ value given.
- The safe bearing pressure of the rock strata is 2500 kN/m^2 .

In this question, it is expected that candidates should demonstrate their understanding of the unbalanced lateral earth pressure emanating from the sloping ground and the hydrostatic uplift pressure due to the presence of ground water.

The methods of excavation of the slope and the related temporary works needed to retain the earth should be explained with simple sketches to demonstrate the understanding of earth retaining and stabilising systems.

Possible solutions

The question requires two distinct and viable solutions. It is important that the candidates understand the real meaning of this requirement for scoring good marks and at the same time recognise the particular intricacies of the question necessary to pass the Chartered Membership Examination.

“Distinct” in the context of the Chartered Membership Examination does not merely mean using different materials for the same layout. “Viable means” that the structure can be safely built.

This question is typical of city centre commercial developments with underground parking. The objective of the question is to challenge candidate’s spatial awareness and ability to design both superstructure and substructure in a site surrounded by busy roads.

The following factors should be developed to achieve the two schemes required by the question.

- It is possible that either concrete or steel schemes could be adopted for this question. However, the design appraisal should show distinct and viable solutions for both schemes/options. This could be achieved by selecting different layouts and floor systems with concrete and steel as dominant structural materials.
- Different layouts could be achieved by adopting dissimilar column spacing without impinging on the functional requirements and client’s brief.
- Adopting different foundation systems such as cast in-situ bored pile and raft foundation. It is anticipated that a cast in-situ bored pile system is preferred for both schemes. A raft foundation solution, albeit difficult to construct, may be an option, acknowledging consideration of differential settlement between the concourse and office footprints (note – a precast RC driven pile system is not preferable in city centre locations.)
- A secant pile retaining wall solution is anticipated due to the presence of roads around the building and the water table. It is imperative that all the construction works should be within the site boundary. However, the basement construction could straddle the boundary line by agreement with the adjoining owners, if the local practice normally allows it. Ground anchors used to restrain retaining walls against earth pressure would be a credible solution provided mention of obtaining statutory approvals is made in the answer.

Further, the engineering is relatively straightforward to balance wide scope of considerations involved to design this building. Key considerations are;

- Merging grids for more open plan offices and lower level parking.
- Appreciation of the spatial constraints imposed by the brief.
- Waterproof basement construction and consideration of buoyance forces on the lowest basement (L3) level floor slab.
- Out of balance earth pressures emanating from the sloping site.
- Basement level buildability.

It is vital that the carpark layout planning should consider the circulation and ramp.

The available structural zones are relatively generous. Therefore, economic solutions are expected from candidates. Candidates who recognise the smaller volume in envelop and excavation costs will gain marks.

Partial possession of adjoining footpaths with pedestrian/vehicular circulation being maintained by temporary traffic control measures is necessary in a larger city centre from a health and safety point of view.

Many distinct and viable solutions are possible for this question when considering the above features with different combinations of structural systems, load transfer and construction methods and materials. Clearly, reinforced concrete or structural steel could be selected as dominant materials for this questions.

Selection of scheme

The following salient features could appropriately be considered in recommending the scheme considering the pros and cons of each scheme,

Economy	Buildability	Safety	Robustness	Durability
Site constraints	Speed of construction	Aesthetic	Acoustics	Thermal mass
Sustainability	Vibration	Fire resistance		

The following distinct and viable schemes are proposed as solutions to this question.

Scheme 1 – Cast in-situ reinforced concrete building on cast in-situ bored piles and a secant bored pile retaining wall

The structural system adopted for the Scheme 1 is explained below;

This Scheme uses a central row of columns within the offices with a transfer structure at Level 1 above the car parking aisle. Car parking layout has longitudinal central aisles below the offices and concourse with parking bays either side. Parking grid arranged with columns between bays co-incident with the superstructure grid and slightly set back from the aisle edges to enhance visibility in the parking floors.

The structural system adopted for the floors adopts conventional reinforced concrete beams and slabs supported on reinforced concrete columns and walls resting on pile caps except in those areas at L1 where transfer columns are present and supported on transfer beams.

Two way “waffle” slabs could be adopted in places where the layout requires 9m x 9m and 9m x 12m floor panels. Alternatively, secondary RC beams could be used with one way slab (the floor layout given in this solution could be amended to suit).

Permanent secant pile walls are used to retain the lateral loads due to surcharge and earth formed by the basement excavation. Secant pile walls are to be permanent and are socketed into the rock to arrest sliding, overturning and also to prevent deep seated failures due to extreme conditions created in the surroundings by future construction activities. In the permanent condition, floors at Level 1 to Level -3 prop the secant pile walls. Therefore, it is necessary to consider the rest condition in the design of the secant pile wall in the permanent condition and the related lateral forces should be resisted by the structure. Hence, K_0 should be used to calculate the lateral forces created by earth and surcharge pressures at permanent conditions. However, it is also necessary to consider the temporary stage in active condition during excavation of the basement. Hence, it is very important to maintain the stability of the structure and the excavated basement during both temporary and permanent stages. In-situ RC flush should be provided to the secant pile walls to get a smooth surface and to receive waterproofing to prevent dampness and vapour in real conditions. Cast in-situ bored pile system is chosen to support the building.

Vertical loads transfer

The gravitational forces arising from dead loads, superimposed dead loads and live loads are supported on slabs that transfer the loads to reinforced concrete beams and walls through bending and shear action. The beams in turn transfer the loads to reinforced concrete columns and walls/retaining walls through bending and shear action. The internal central row of columns in the office floors transfer the load to transfer beams at Level 1 by bending and shear action. The transfer beams in turn transfer the loads to columns by bending and shear action.

The columns and walls via bending and shear actions transfer the loads to pile caps. Pile caps then transfer the loads to cast in-situ bored piles through bending and shear action. Cast in-situ bored pile foundation and secant pile retaining walls transfer the loads to the ground by friction and bearing actions.

Hydrostatic water pressure created by water uplift is resisted by the base at L-3 by bending and shear and transferred to the piles through pile cap.

Lateral loads transfer

Lateral wind load is resisted by façade elements and transferred to floors and roof by bending and shear action. Diaphragm action of the floors and roof transfers the load to cores and columns through bending and shear action. Then, cores and columns in combination resist the wind forces and transfer them by bending and shear actions to pile caps supported on cast in-situ bored pile foundations that transfer the loads to the ground by friction and bearing action.

Secant pile retaining wall resist the earth, surcharge and water pressures by bending and shear actions and transfer the lateral loads to the floors. Out of balance earth pressures across the change in site level will be resisted by cores and the gable end walls.

Movement Joint

Consideration of movement joints are necessary in large concrete buildings. The requirements and local practices varies from country to country based, inter alia, on climatic conditions. Therefore, design appraisal should include the requirements of movement joint as appropriate based on the local requirements (the annotated sketches attached do not show any movement joint deliberately). For instance, in the context of this question, a movement joint is required as per UK practice since the building length is more than 50m but a movement joint may be avoided in other countries if the local practice allows for a length up to 90m (the length of the building in this case).

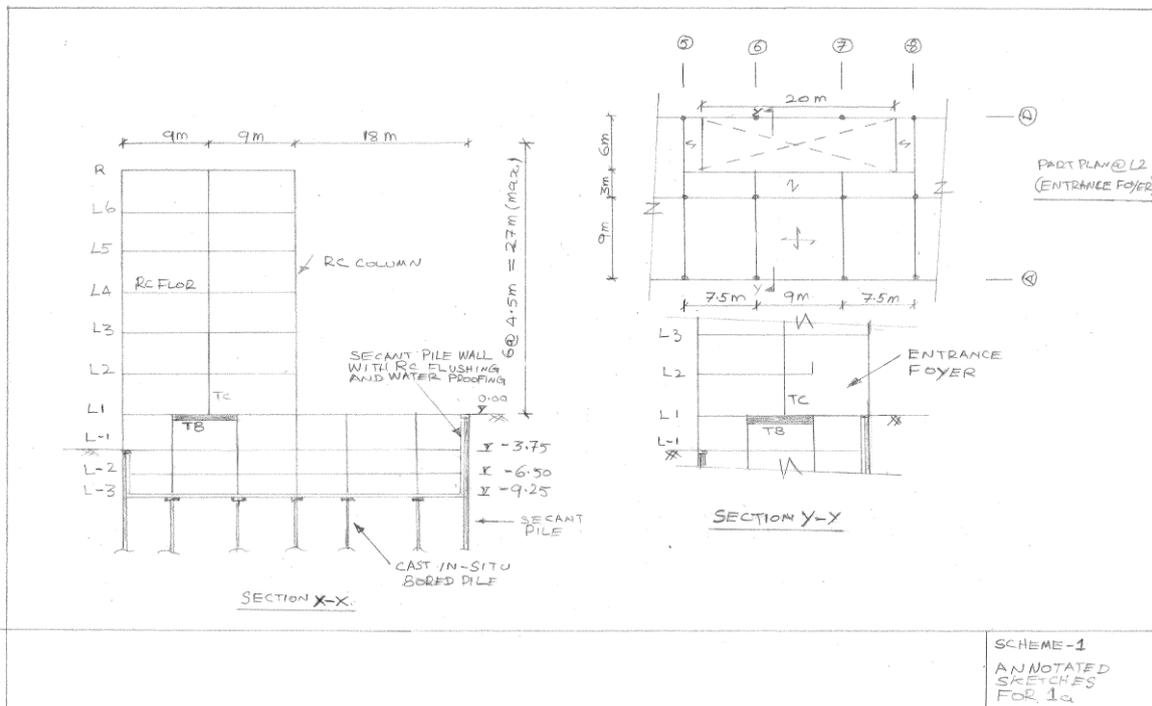
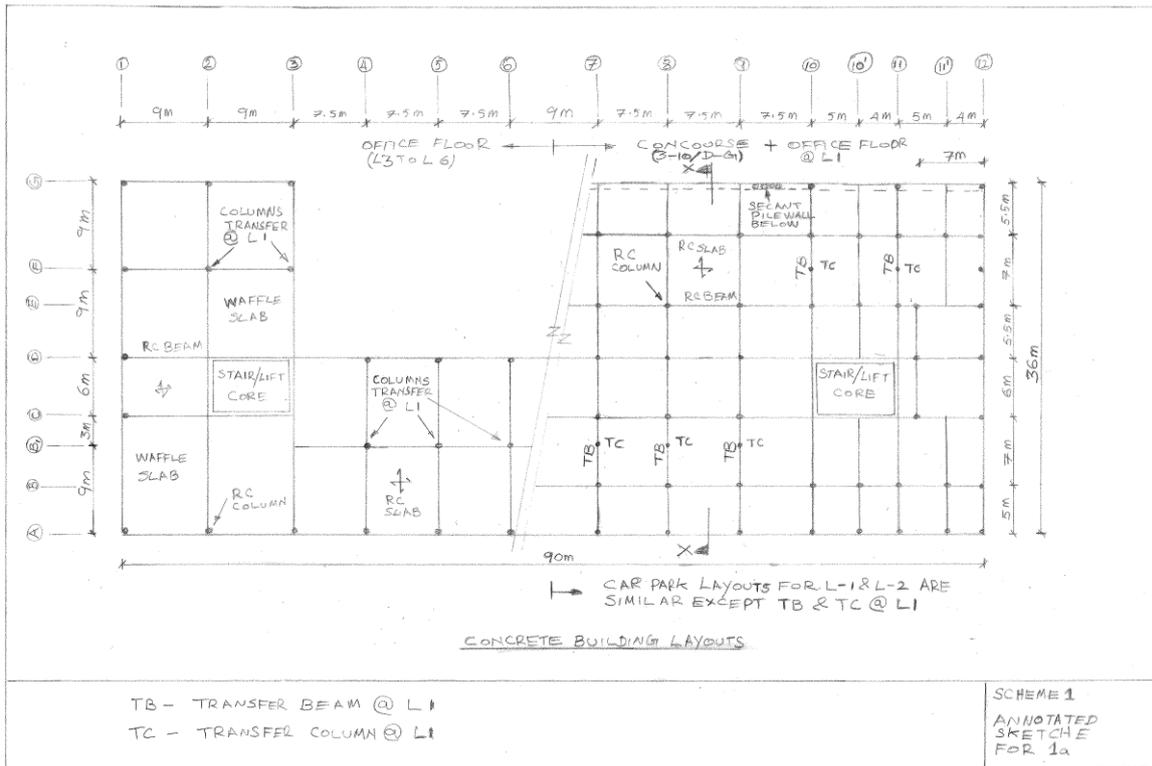
Robustness and stability

All the beam and column connections should be monolithic/continuous to achieve robustness and stability. The parking floors should be connected to secant pile wall. It is beneficial to include a few rows of columns in the middle to resist the lateral forces considering the length of the building though cores attract a mayor portion of lateral forces. This must be carefully explored in the detailed design.

Durability/Fire resistance

The question did not specify the fire rating requirements. However, considering the height of the building a 2-hour fire rating is adopted. The concrete cover should be selected in such a way to comply with the durability and fire resistance for 2-hour.

Annotated sketches depicting the layout and section complying with the client's brief are shown below.



Scheme 2- Steel building on cast in-situ bored pile and secant bore pile retaining wall

The structural system adopted for the Scheme 2 is explained below;

This scheme sets the single row of internal office columns 6m eccentrically from the elevations. This generally allows the columns to continue down through the carpark avoiding the need for transfer structure above the car parking aisle. However, the layout demands a transfer structure in two locations at L1 as shown in the layout, to facilitate the ramp and to gain access to the parking lot.

The structural system adopted for the floors is composite steel decking supported on steel columns and walls connected to pile caps resting on cast in-situ bored piles.

The retaining wall system for the carpark basement and the foundation system are same as in Scheme 1, viz secant bored pile and cast in-situ bored pile respectively.

Vertical loads transfer

The gravitational forces arising from dead load, superimposed dead load and live load are supported on slabs that transfer the loads to secondary steel beams and walls through bending and shear action. Those secondary steel beams in turn transfer the loads to primary steel beams connected to steel columns and reinforced concrete walls through bending and shear action.

The columns and walls then transfer the loads to reinforced concrete pile caps through bending and shear action. Pile caps then transfer the loads to cast in-situ bored piles through bending and shear action. The cast in-situ bored piles and secant pile retaining wall transfer the loads to ground via friction and end bearing.

Hydrostatic water pressure created by water uplift is resisted by base at L-3 by bending and shear and transferred to the piles through the pile caps.

Lateral loads transfer

Wind load is resisted by façade elements and is transferred to floors, roof and vertical bracing by bending and shear action. Diaphragm action of the floors and roof transfers the load to columns, walls and vertical bracing through bending and shear action.

Walls and columns then transfer the lateral loads through bending and shear actions to the pile caps. Vertical bracings resist the lateral forces through resulting axial forces in them and in turn transfer the forces to columns. Pile caps then transfer the loads to cast in-situ bored piles through bending and shear action. The cast in-situ bored piles transfer the loads to ground via friction and end bearing.

Secant pile retaining wall resist the earth, surcharge and water pressures by bending and shear actions and transfer the lateral loads to floors. Out of balance earth pressures across the change in site level will be resisted by cores and the gable end walls.

Robustness and stability

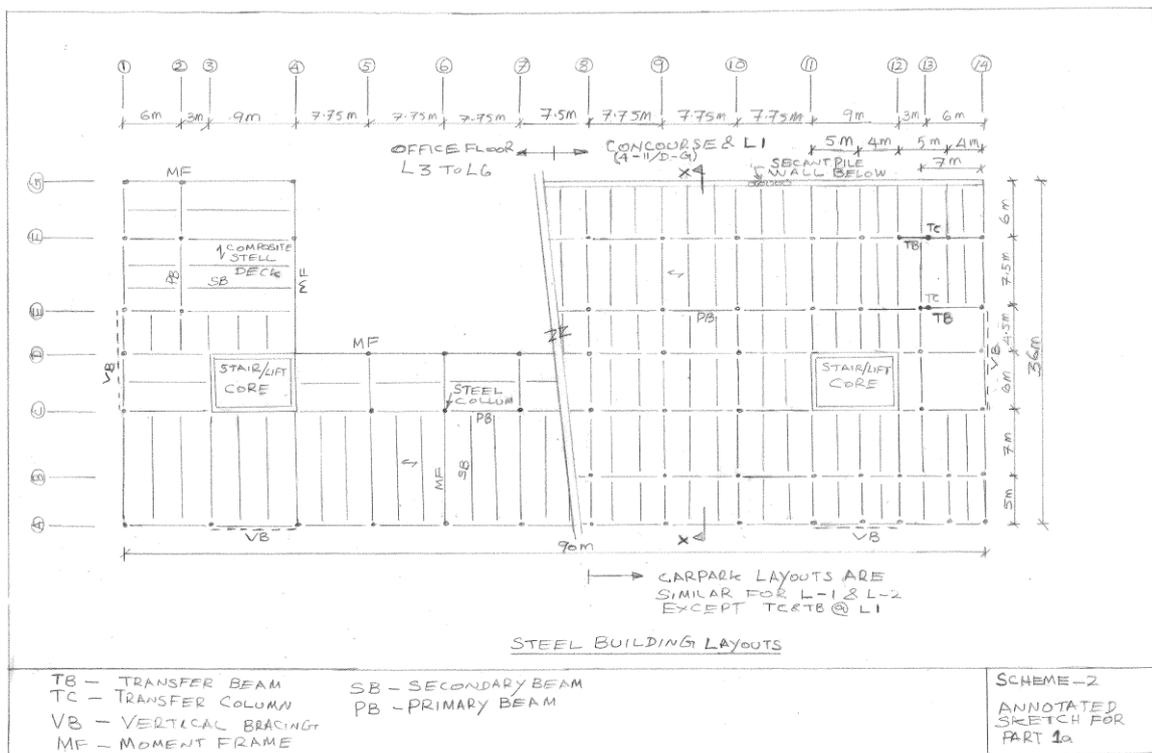
All the beam and column connections in the front and concourse elevations should be moment connections to achieve robustness and stability. Core walls and vertical bracing contribute to the stability and improve the robustness. It is beneficial to include a few rows of columns in the middle to resist the lateral forces considering the length of the building though cores attract a mayor portion of lateral forces. This must be carefully explored in the detailed design to get an appropriate balance between moment connections and simple shear connections.

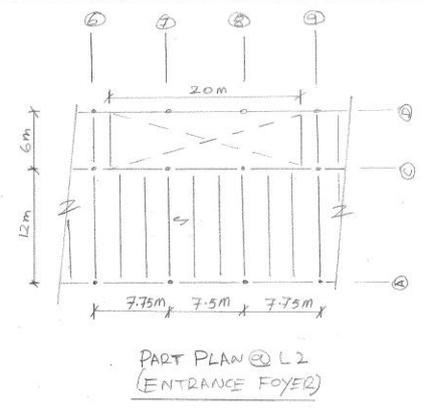
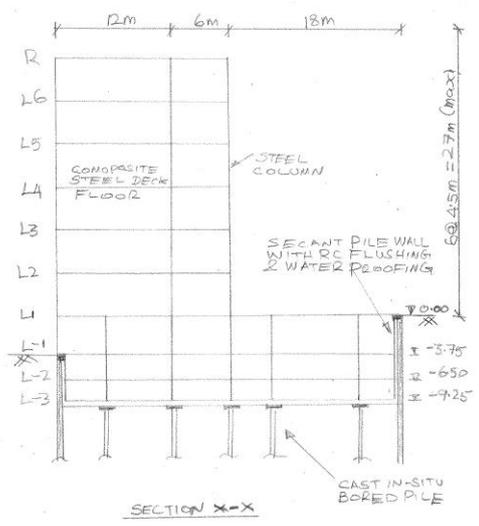
Durability/Fire resistance

The question did not specify the fire rating requirements. However, considering the height of the building a 2-hour fire rating is adopted. The concrete cover should be selected in such a way to comply with the durability and fire resistance for 2-hour.

All the structural steel elements should be provided with suitable fire coating to withstand the 2-hour fire rating.

Annotated sketches depicting the layout and section complying with the client’s brief are shown below.





SCHEME 2
ANNOTATED
SKETCHES

The Letter

The letter tests the competency of the candidates in dealing with a design change situation after the completion of the detailed design as often occurs in real practice. It should be written effectively to communicate the structural implications to a non-technical reader.

The design change situation in this question requires that the half of the building is to be constructed in an initial phase.

The following points depict the consequences of constructing half of the building in an initial phase.

- The layout with one single core will create torsion in the building due to loss of symmetry when constructing half of the building first. The stability issues of a single core need to be explained in the letter.
- It is required that the construction should support the floors along the outline in the centre and extension of retaining wall across the centre of the site.
- Ramp and vehicle circulation need revising.
- Entrance foyer needs relocation.
- The overall cost of the project would increase when the second half of the building is constructed in later stage.

It is worth noting the following,

- The structural implications could be explained using appropriate sketches in this part of the question.
- If the structural implications of the design change requirement seems trivial to the candidate then it implies that he/she has disregarded an essential part of the question.
- The letter should give importance to explaining the structural aspects of the design change and not over emphasise the business aspect related to additional fees.

Summary

This question is a straight forward question for those who possess good experience in the design and construction of concrete structures, steel structures and earth retaining and stabilising systems.

Arriving at two distinct and viable solution becomes possible when the inherent characteristics of these systems are suitably utilised and combined in the appraisal to deal with different materials, load paths and construction methods.

Concrete and/or steel structures could be adopted for this building.

It is also important to demonstrate in the answer that stability of the structure is maintained for both the temporary and permanent condition. Stability checks for over turning and sliding must be provided based on the elements sizes obtained.

The **Institution**
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Engineers

Possible solution to past CM examination question

Question 3 - January 2015

Temporary pedestrian bridge

by Saprava Bhattacharya

The information provided should be seen as an interpretation of the brief and a possible solution to a past question offered by an experienced engineer with knowledge of the examiners' expectations (i.e. it's an individual's interpretation of the brief leading to one of a number of possible solutions rather than the definitive "correct" or "model" answer).

Question 3. Temporary pedestrian bridge

Client's requirements

1. A temporary pedestrian bridge is required to provide access from the shore to an existing jetty serving passenger ferries: see Figure Q3. The temporary bridge is needed while the jetty is extended, putting the permanent access bridge out of use. Access for fishermen's boats is required under the temporary bridge.
2. The tidal range is 2.0m, from +0.5m high water to -1.5m low water. Datum is Mean Sea Level (MSL). The bridge is to be 150m long and to provide a 4.0m clear width for pedestrians. The jetty is 100m away from the shore at low water. A minimum clearance of 3.5m is required under the bridge at all states of the tide, over an uninterrupted length of 50.0m and a second uninterrupted length of 20m within the 100m distance between the jetty and shore.
3. No temporary or permanent foundations may be installed closer than 75.0m to the jetty. The client advises that the existing jetty is capable of supporting unfactored loads of 500kN vertically and 250kN laterally in both horizontal directions from the temporary bridge. The existing jetty deck level is +4.5m above MSL.
4. In the 50.0m length of bridge over the tidal zone of the shore, no construction may leave any footprint after the bridge is removed.
5. All existing services should remain uninterrupted during the construction, use and removal of the bridge. There is a 30.0m-high electricity transmission tower and line close to the proposed bridge which will remain live throughout the construction, use and removal of the bridge.

Imposed loading

6. Live load on bridge deck. 5.0kN/m²

Site conditions

7. The site is located in the open sea. Basic wind speed at sea level is 46.0m/s based on a 3-second gust; the equivalent mean hourly wind speed is 23.0m/s.
8. Ground Conditions

Sea bed – 30m below datum	Stiff clay, $C = 200\text{kN/m}^2$
30m - depth	Rock, characteristic compressive strength 1,000kN/m ²

Omit from consideration

9. Longitudinal imposed loading.

SECTION 1

(50 marks)

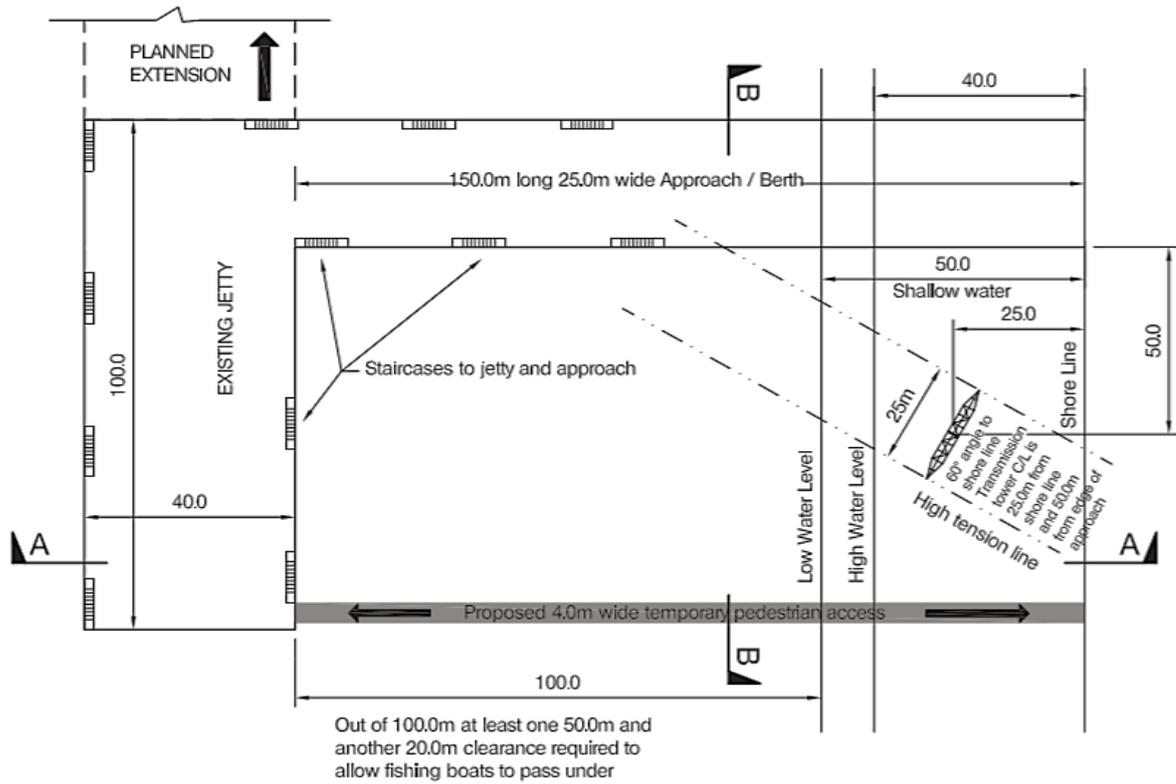
- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After the completion of the design the client advises that a mistake was made in the calculation of the jetty load capacity, and the correct values are 50% of those previously advised in both the horizontal and vertical directions. Write a letter to your client advising of the implications this would have on your design and ways in which the design could be modified. (10 marks)

SECTION 2

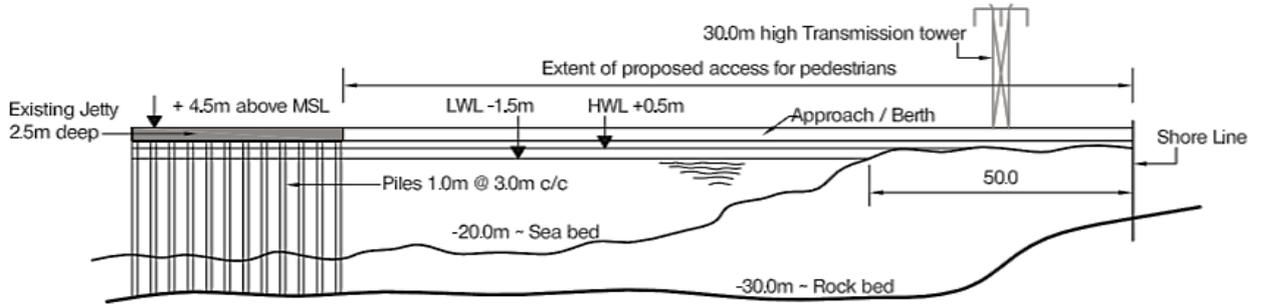
(50 marks)

For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20 marks)
- e. Prepare a detailed method statement for the safe construction of the works and an outline construction programme. (10 marks)

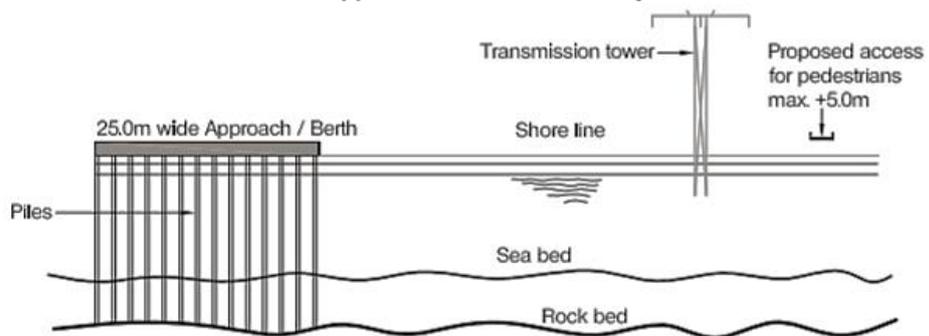


PLAN OF EXISTING JETTY AND APPROACH



SECTION A - A

(Piles under Approach not shown for clarity)



SECTION B - B

NOTE: All dimensions are in metres

FIGURE Q3

Question 3. Temporary pedestrian bridge

Question 3

Client's requirements

1. A temporary pedestrian bridge is required to provide access from the shore to an existing jetty serving passenger ferries: see Figure Q3. The temporary bridge is needed while the jetty is extended, putting the permanent access bridge out of use. Access for fishermen's boats is required under the temporary bridge.
2. The tidal range is 2.0m, from +0.5m high water to -1.5m low water. Datum is Mean Sea Level (MSL). The bridge is to be 150m long and to provide a 4.0m clear width for pedestrians. The jetty is 100m away from the shore at low water. A minimum clearance of 3.5m is required under the bridge at all states of the tide, over an uninterrupted length of 50.0m and a second uninterrupted length of 20m within the 100m distance between the jetty and shore.
3. No temporary or permanent foundations may be installed closer than 75.0m to the jetty. The client advises that the existing jetty is capable of supporting un-factored loads of 500kN vertically and 250kN laterally in both horizontal directions from the temporary bridge. The existing jetty deck level is +4.5m above MSL.
4. In the 50.0m length of bridge over the tidal zone of the shore, no construction may leave any footprint after the bridge is removed.
5. All existing services should remain uninterrupted during the construction, use and removal of the bridge. There is a 30.0m-high electricity transmission tower and line close to the proposed bridge which will remain live throughout the construction, use and removal of the bridge.

Imposed loading

6. Live load on bridge deck. 5.0kN/m²

Site conditions

7. The site is located in the open sea. Basic wind speed at sea level is 46.0m/s based on a 3-second gust; the equivalent mean hourly wind speed is 23.0m/s.
8. Ground Conditions Sea bed – 30m below datum Stiff clay, $C = 200\text{kN/m}^2$ 30m - depth Rock, characteristic compressive strength 1,000kN/m²

Omit from consideration

9. Longitudinal imposed loading.

SECTION 1 (50 marks)

- a. Prepare a design appraisal with appropriate sketches indicating two distinct and viable solutions for the proposed structure. Indicate clearly the functional framing, load transfer and stability aspects of each scheme. Identify the solution you recommend, giving reasons for your choice. (40 marks)
- b. After the completion of the design the client advises that a mistake was made in the calculation of the jetty load capacity, and the correct values are 50% of those previously advised in both the horizontal and vertical directions. Write a letter to your client advising of the implications this would have on your design and ways in which the design could be modified. (10 marks)

SECTION 2 (50 marks)

For the solution recommended in Section 1(a):

- c. Prepare sufficient design calculations to establish the form and size of all the principal structural elements including the foundations. (20 marks)
- d. Prepare general arrangement plans, sections and elevations to show the dimensions, layout and disposition of the structural elements and critical details for estimating purposes. (20 marks)
- e. Prepare a detailed method statement for the safe construction of the works and an outline construction programme. (10 marks)

Introduction: *Figures 1 and 2 show the site in three dimension*

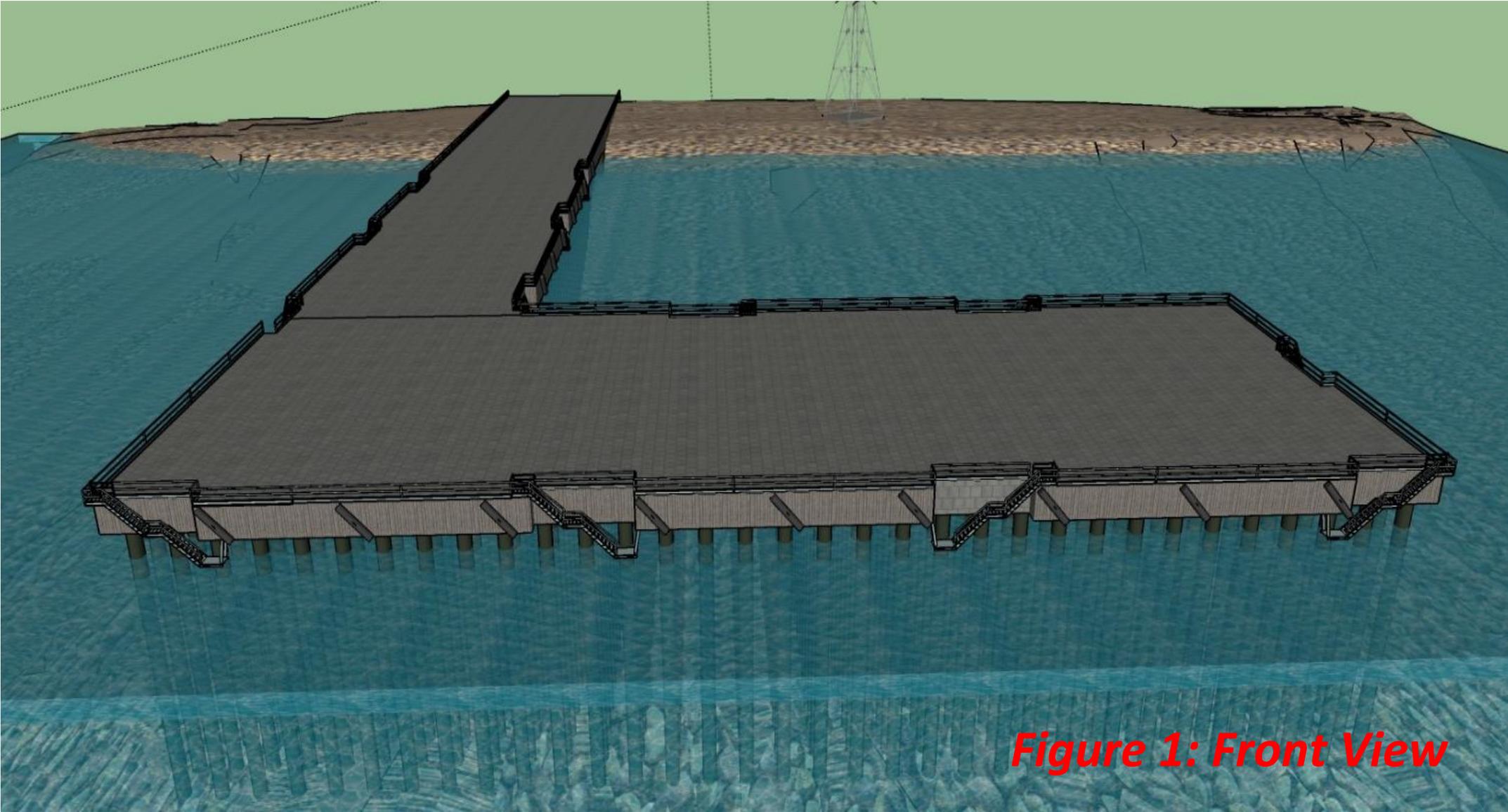


Figure 1: Front View

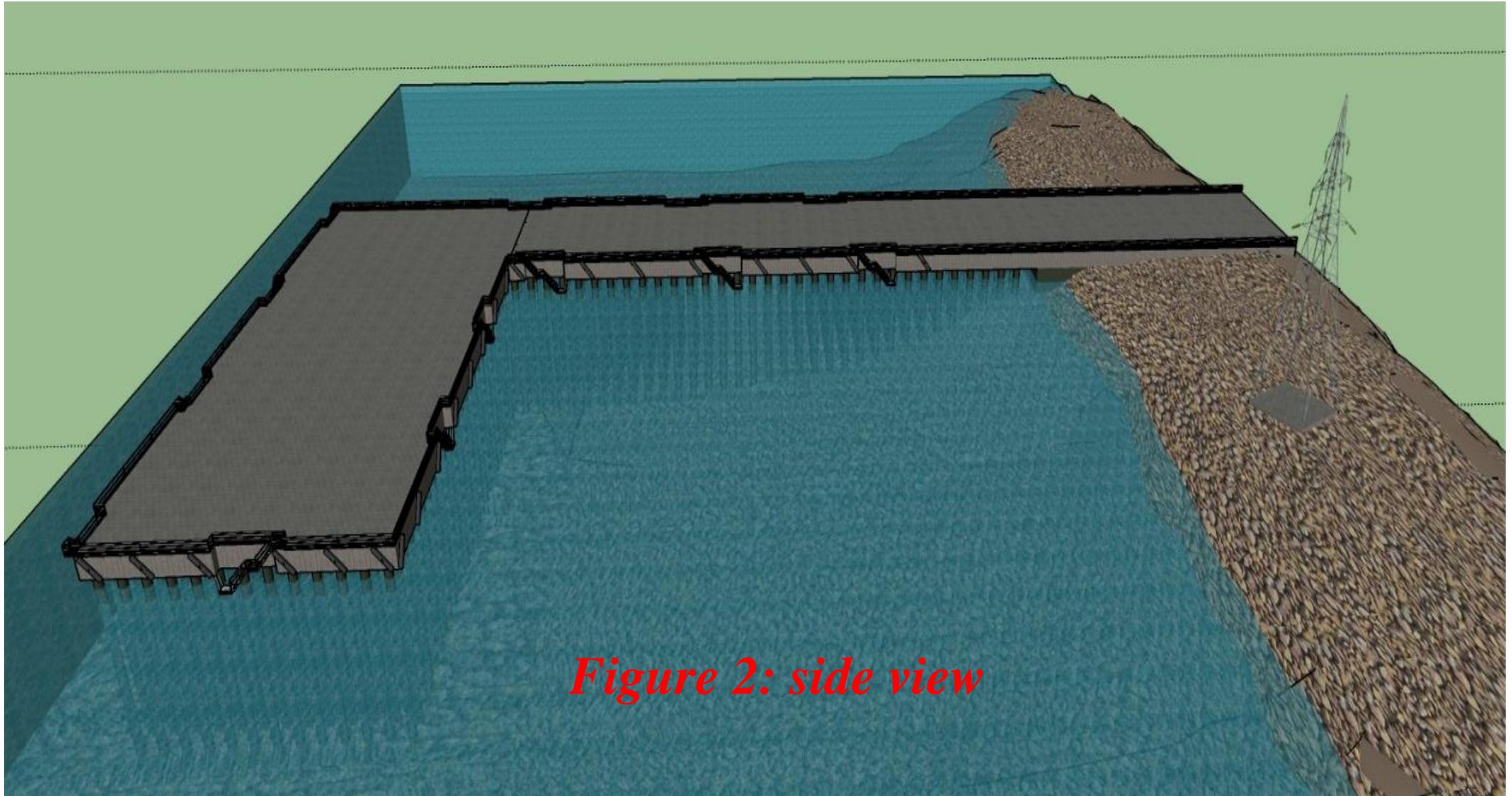


Figure 2: side view

This is a question where engineers are expected to think outside the box to come up with a very simple solution for a complicated problem and not the other way round. This was a real life problem. There are plenty of jetty out there for which similar situation could arise at any point of their service life.

Looking at the client's requirements and the description of the site the only simple solution to the problem is nothing but a pedestrian walkway supported by floating barges at appropriate distance. One of the well-known examples of floating bridge is the temporary bridge prior to construction of present Howrah Bridge at the capital city of Bengal state of India named Kolkata (Figure 3 and 4).

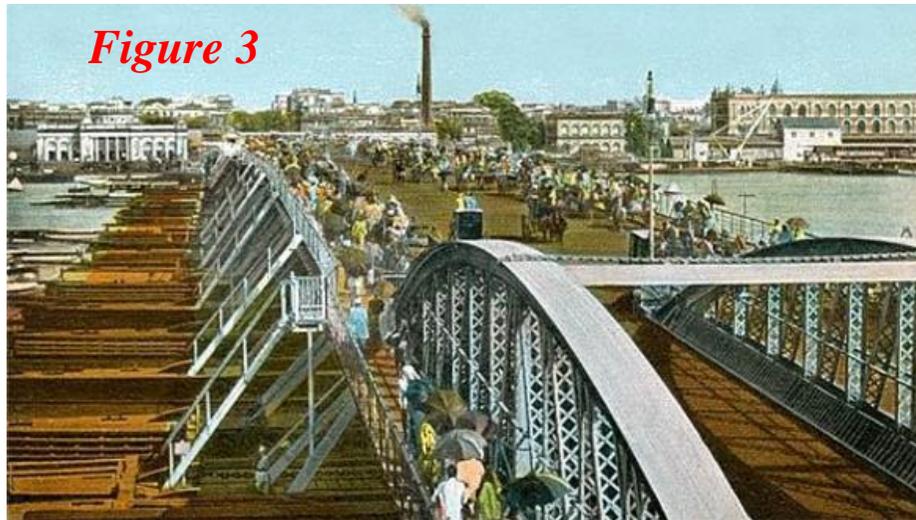


Figure 3

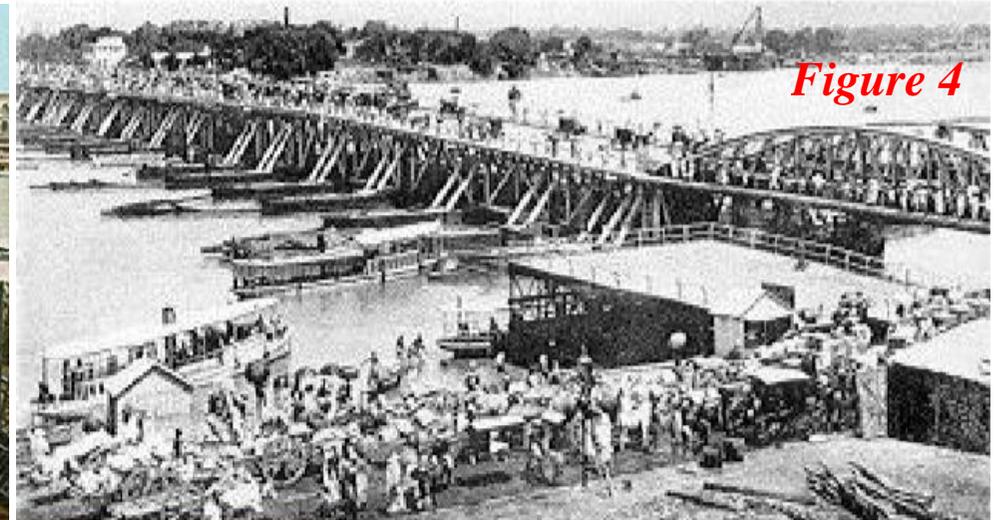


Figure 4



Figure 5

Another example of an existing Floating foot bridge is Canary Warf Bridge (Figure 5)

A simple pedestrian access to a small jetty is a possible way to join two approach trusses to overcome such problem as shown in Figure 6 below. This type of structure could be a

joiner of two Trusses from either end as shown in the solutions shown through figure 7 and further.



Figure 6

Solution 1

Simple truss bridge dropped on top of Pontoons (spans 25m 55m & 25m) resting on Jetty on one end and on temporary embankment at the other end.

This solution is the easiest. Simply supported truss bridges supported on pontoons / floating barges with appropriate overhang to support a simply supported dropping span in between, the basic cantilever bridge concept. Span adjustment could be such that the clearance envelopes are compiled, as well as the reactions on the existing jetty never exceed as mentioned in client's brief. 3D model in figure 9 to 12 as well as sketches in figure 7 & 8 is self-explanatory to demonstrate the simplest possible solution to this particular problem. If required these floating pontoon / barge can be tied back to some form of anchors on seabed. This particular will be the only solution which can really be considered as a pure temporary solution.

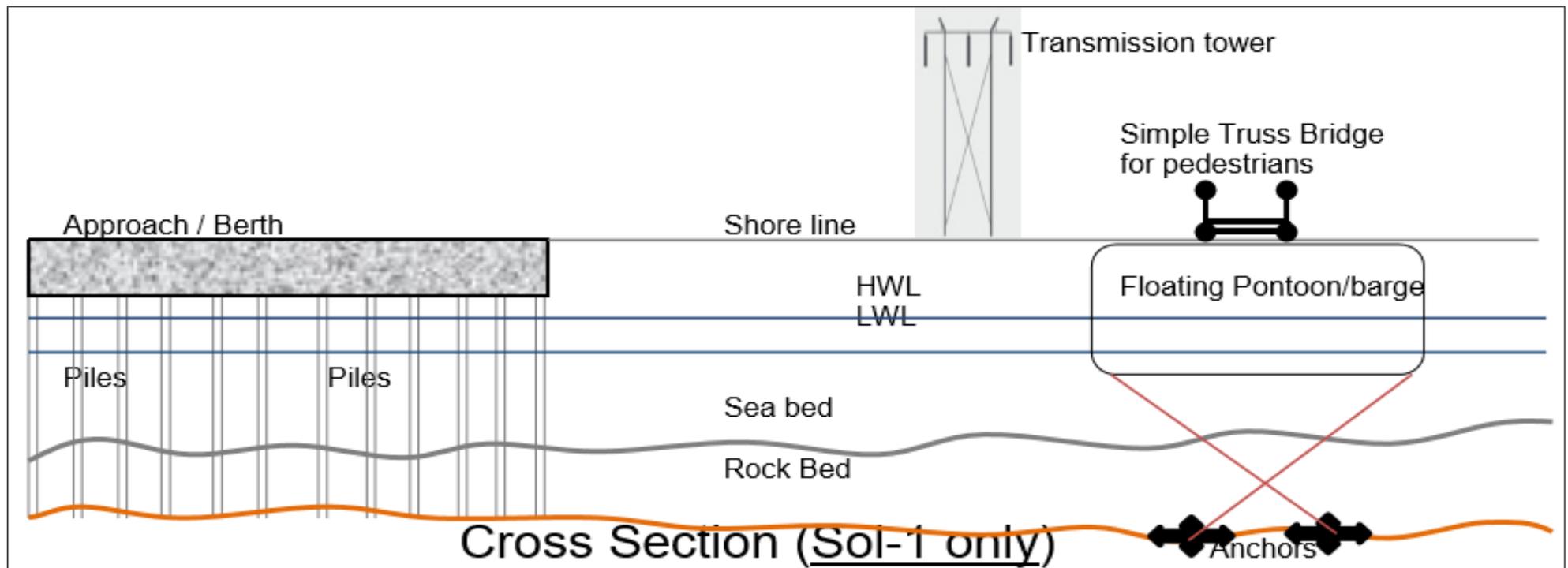


Figure 7 Cross sectional view of the proposed solution 1

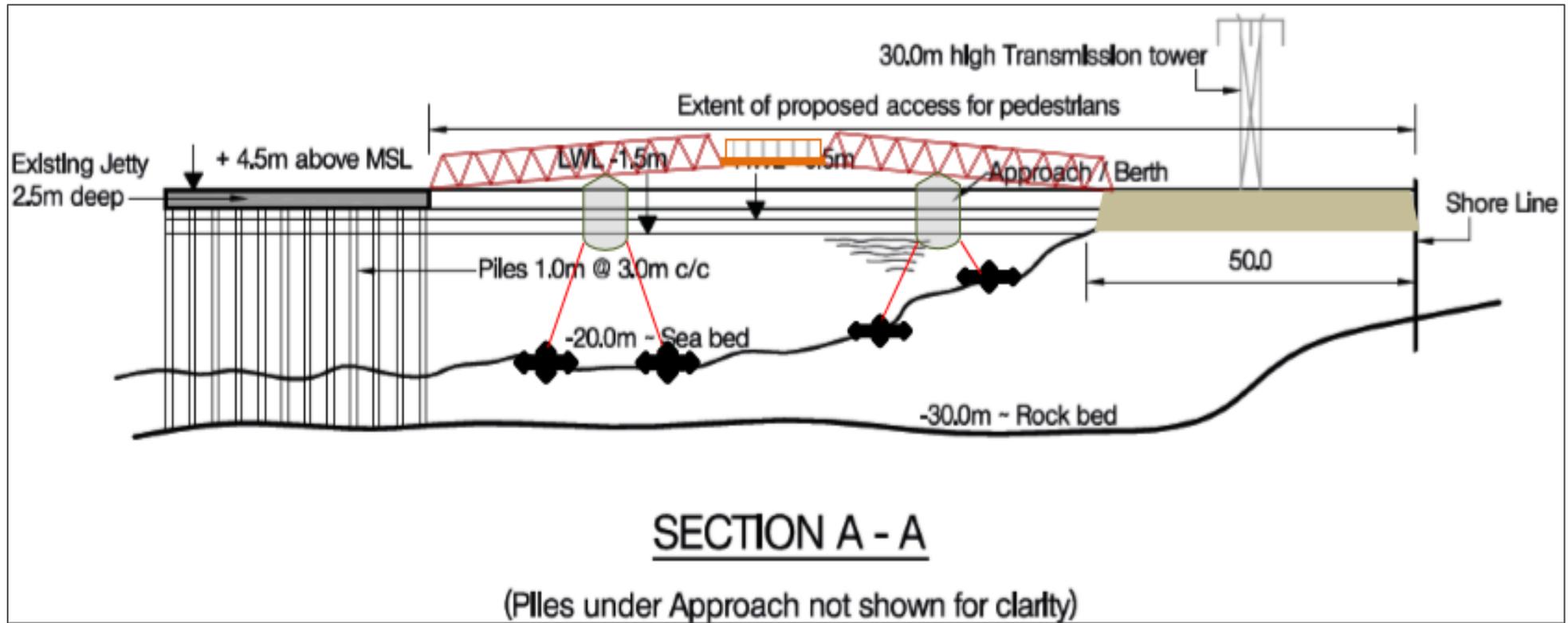


Figure 8 Long sectional view of the proposed solution 1

In the following figures 9 to 12 three dimensional views of the proposed simple solution should be sufficiently self-explanatory to demonstrate its appropriateness.

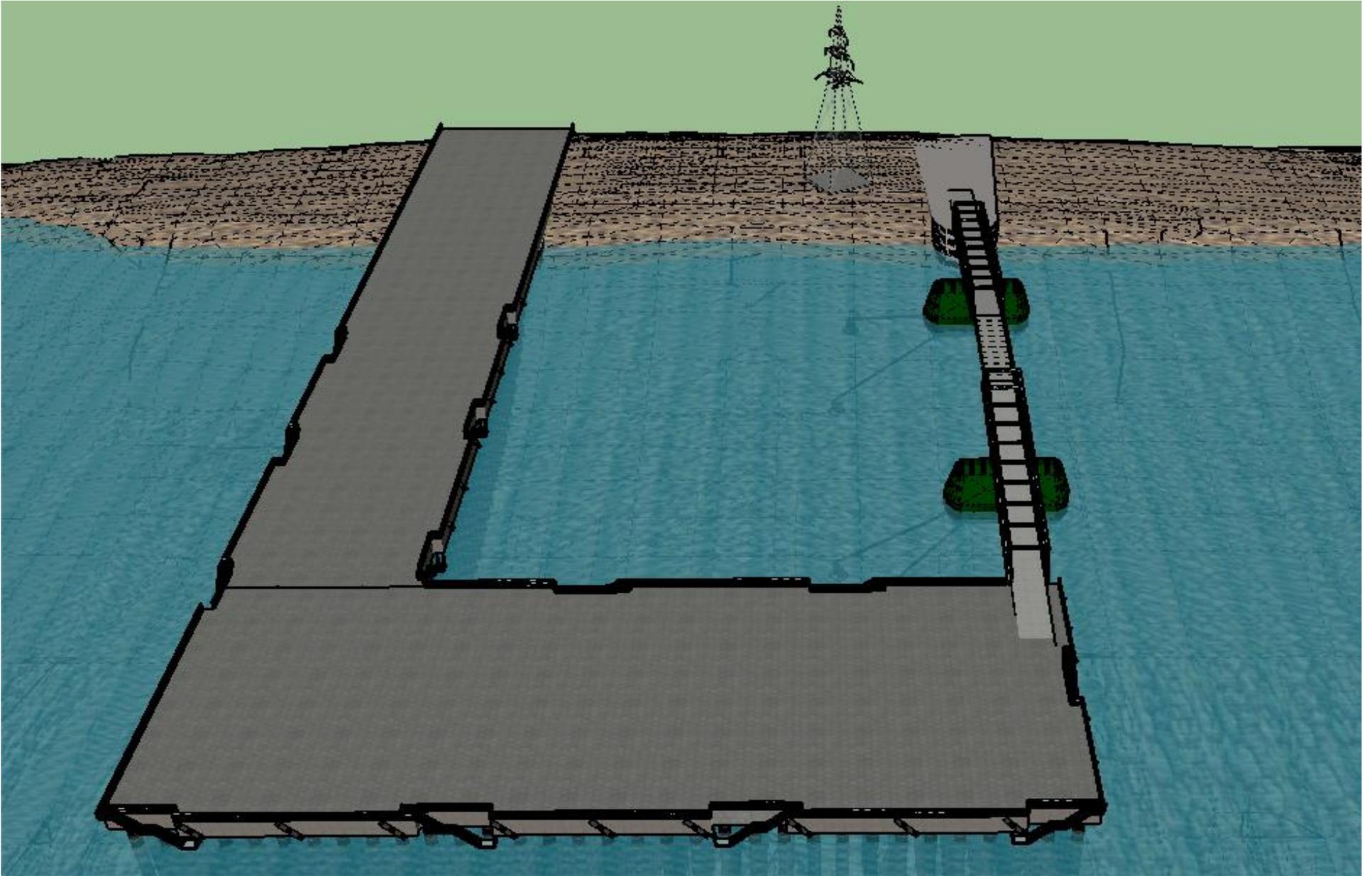


Figure 9

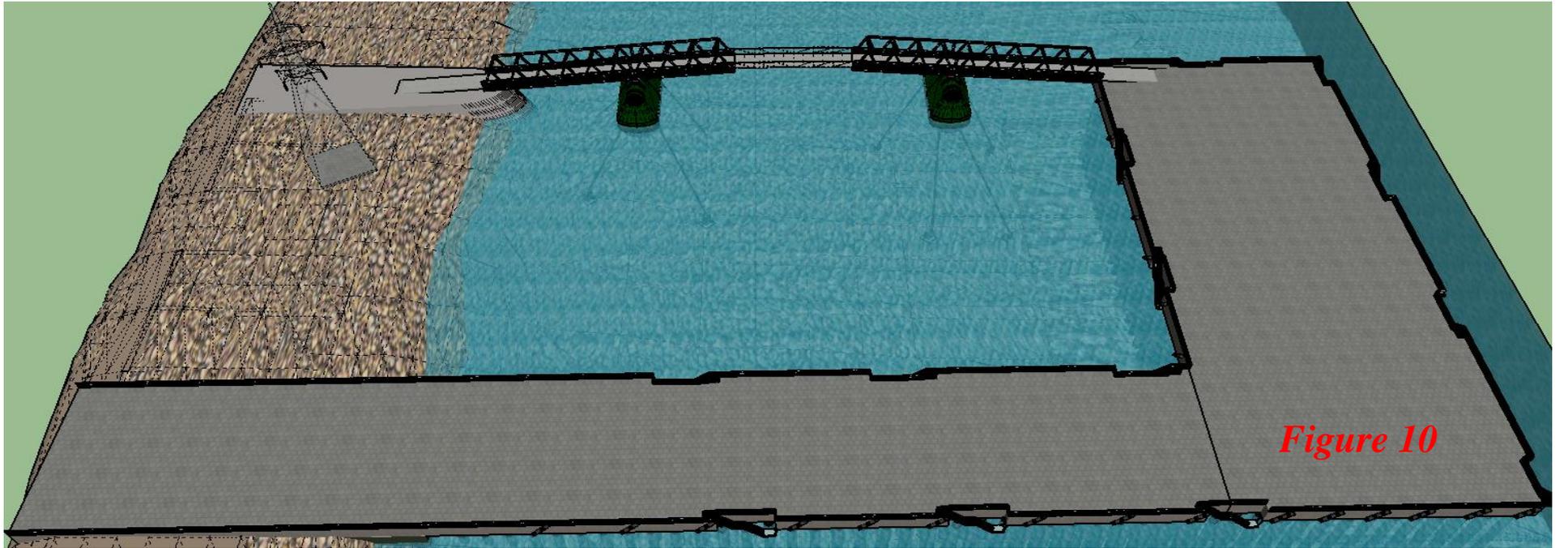


Figure 10

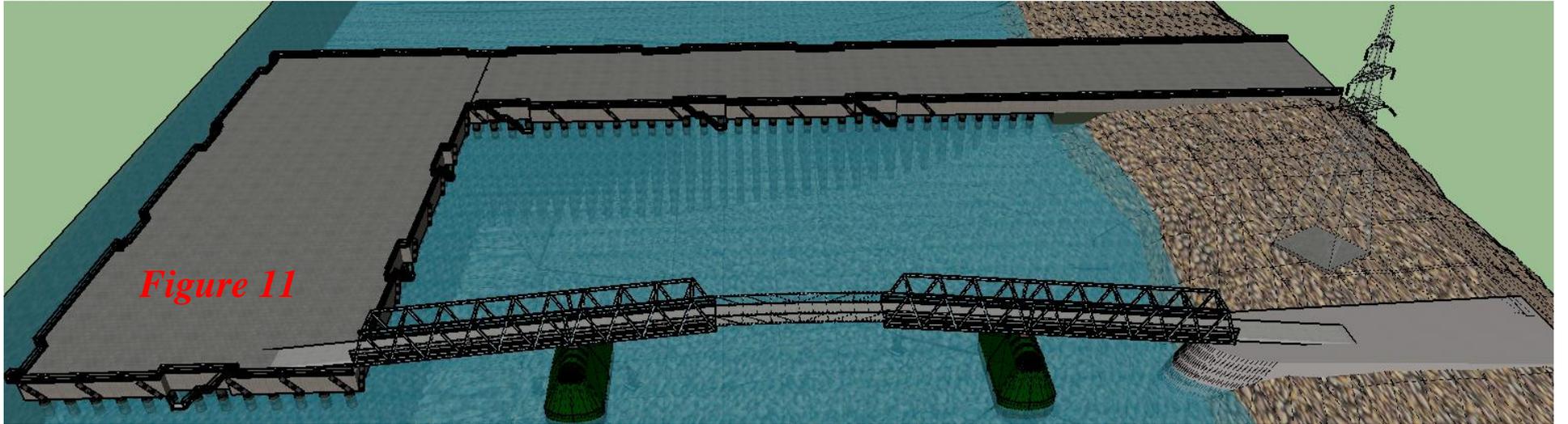


Figure 11

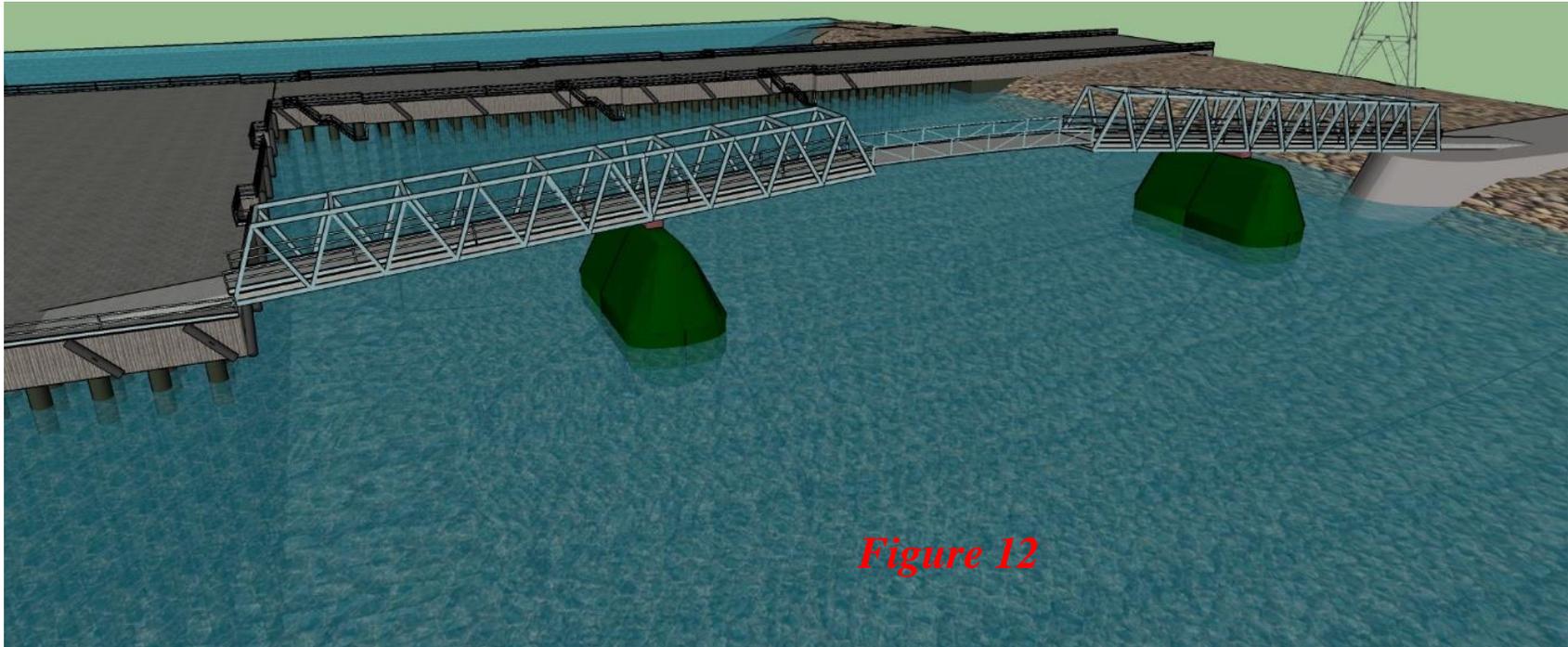
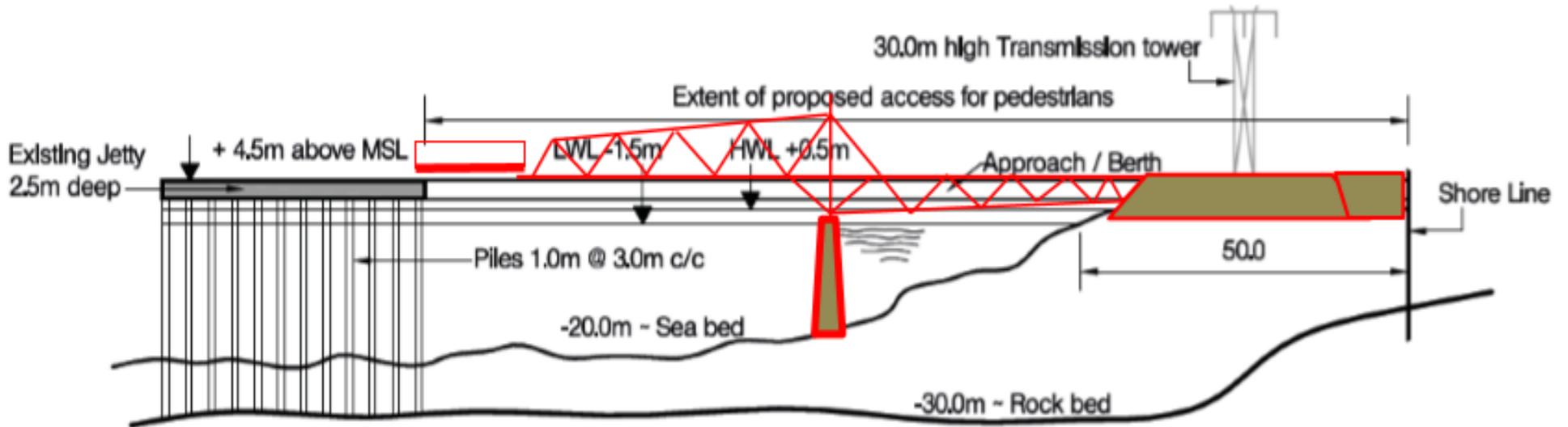


Figure 12

Though the question asks candidates to propose two solutions for a temporary bridge structure, truss superstructure were inevitable. To make them fully distinct from each other, it was essential to propose two truss bridge superstructures whose supporting arrangements are significantly different from each other so that the load path is different.

Solution 2

To be a complete distinct as well a temporary solution - one half of Tokyo Gate Bridge with suspended span can easily be a discarded but feasible solution. The length of the suspended span to be decided based on its reaction to the existing jetty. Precast concrete deck may be used on top of the under slung truss for the approach span to balance some permanent load and avoid any possible uplift at the end abutment when there isn't any live load. Although both the proposed solutions are based on cantilever bridge concept but the load path and structural configuration of both the solutions are totally different in spite of the same material being used. Figure 13 and followed by other figures of three dimensional representations are self- sufficient to demonstrate its appropriateness for this particular problem.



SECTION A - A

(Piles under Approach not shown for clarity)

Figure 13 Long sectional view of the proposed solution 2

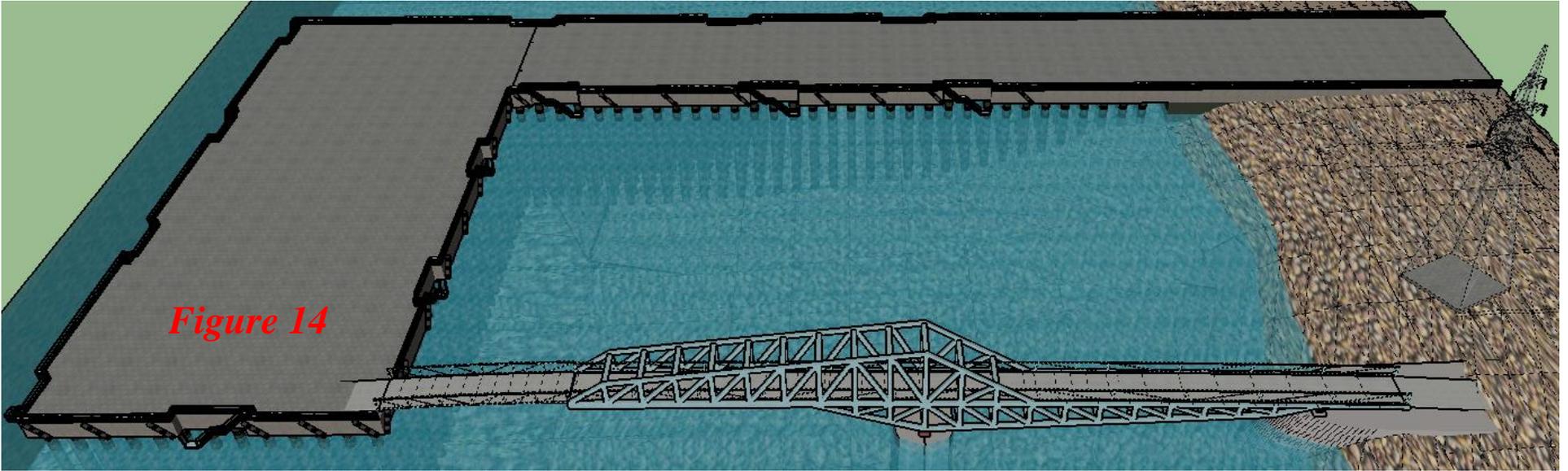


Figure 14

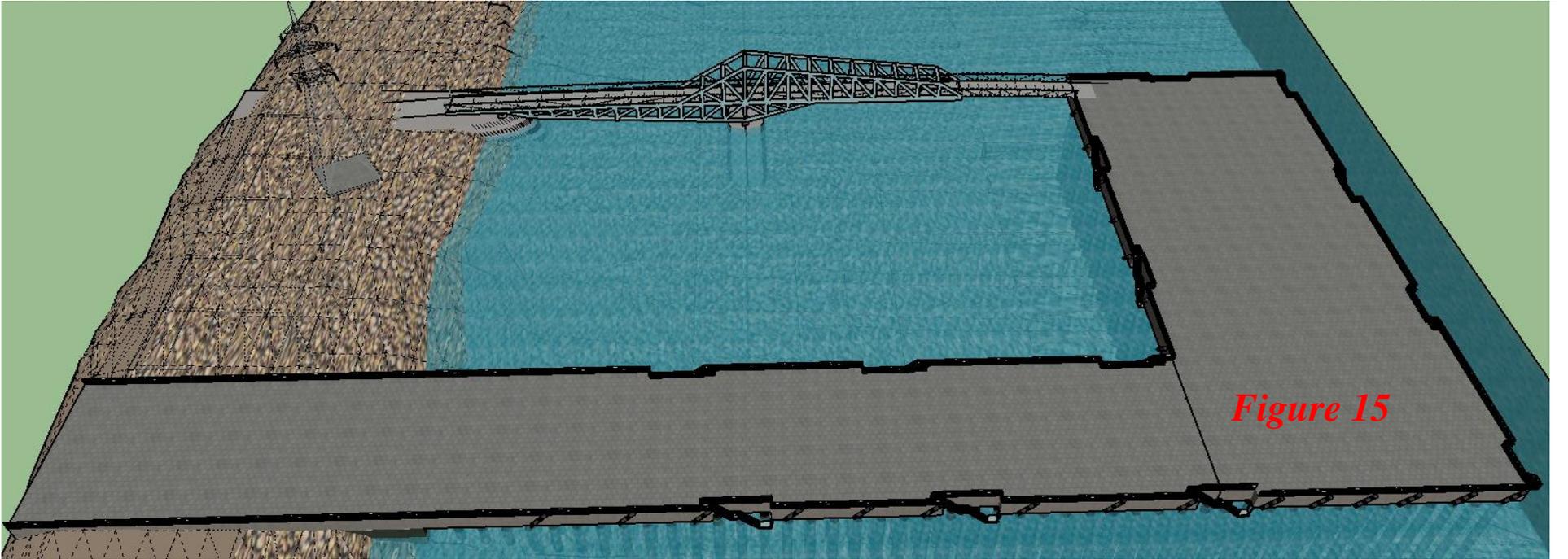


Figure 15

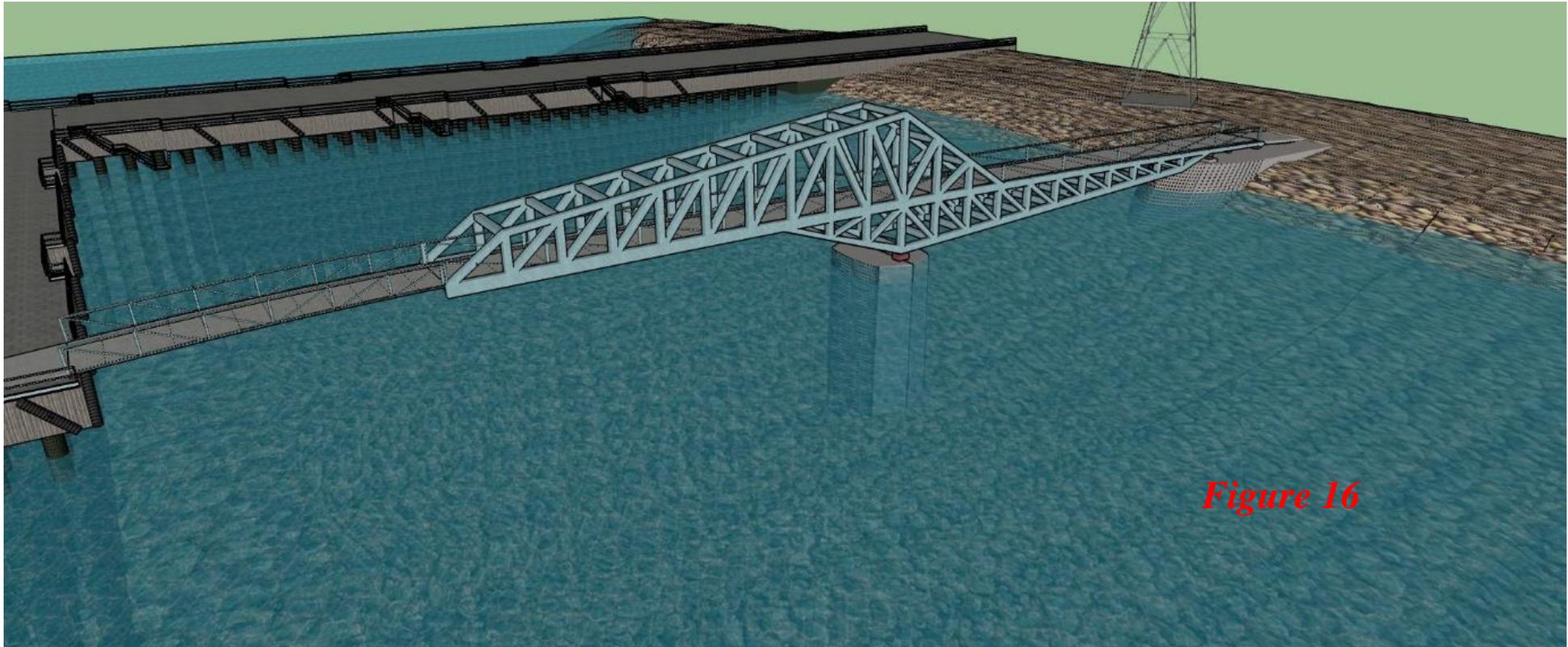


Figure 16

Comparison of two options:

Looking at the two proposals it is obvious that the first solution is much more appropriate to the problem for many reasons.

For Example: Purely temporary structure, least construction period and disruption to the users, much more economical, and many more.

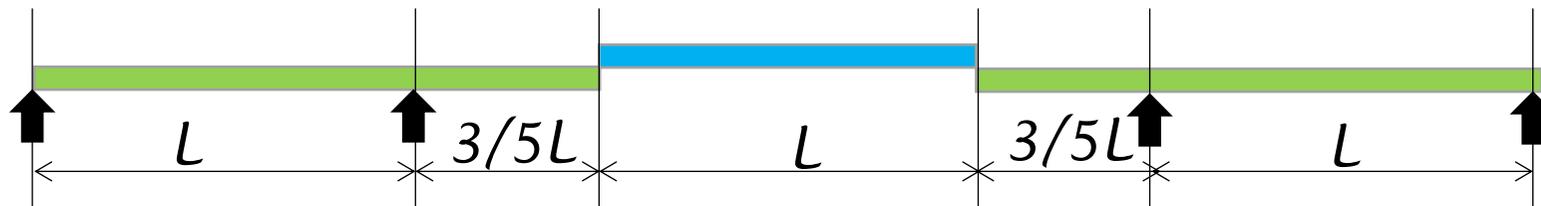
Letter writing:

Controlling support reactions to the given value itself is one of the major challenges for this question. Unless span and structural arrangements are appropriately proposed like the above two solutions it is impossible to meet the given criterion. Therefore it is inevitable to come up with an arrangement which will comply with allowable reaction forces. For the chosen solution it is essential to establish what could be the reactions on the existing Jetty with different patterns of live loading. As per the question, the restriction is on vertical positive reaction, but not on the negative reaction. Letter criterion is also in the same line, hence should be dealt accordingly.

Calculation:

First aim of this part should be to demonstrate the vertical reaction on the existing Jetty

4m wide 5kN/m² LL => 20kN/m. Considering, a conservative approach all other possible vertical loads add up to another 20kN/m allows maximum span of 25m simply supported. For any overhang superstructure for a cantilever bridge arrangement as considered, the reaction at the support on top of the existing jetty can never reach 500kN. In fact an Influence line diagram for the end support reaction will confirm that.



The main trusses at either end will have bottom cord in compression whereas in the top cord of the suspended span. The compression force in them can easily be worked out from the BMD of the above idealised single line beam model and designed accordingly. Use of RHS could easily be adopted.

Drawings

Further improvement in figure 7 and 8 and adding few cross sections of the bridge superstructures could be sufficient as general arrangement drawing for the chosen solution.

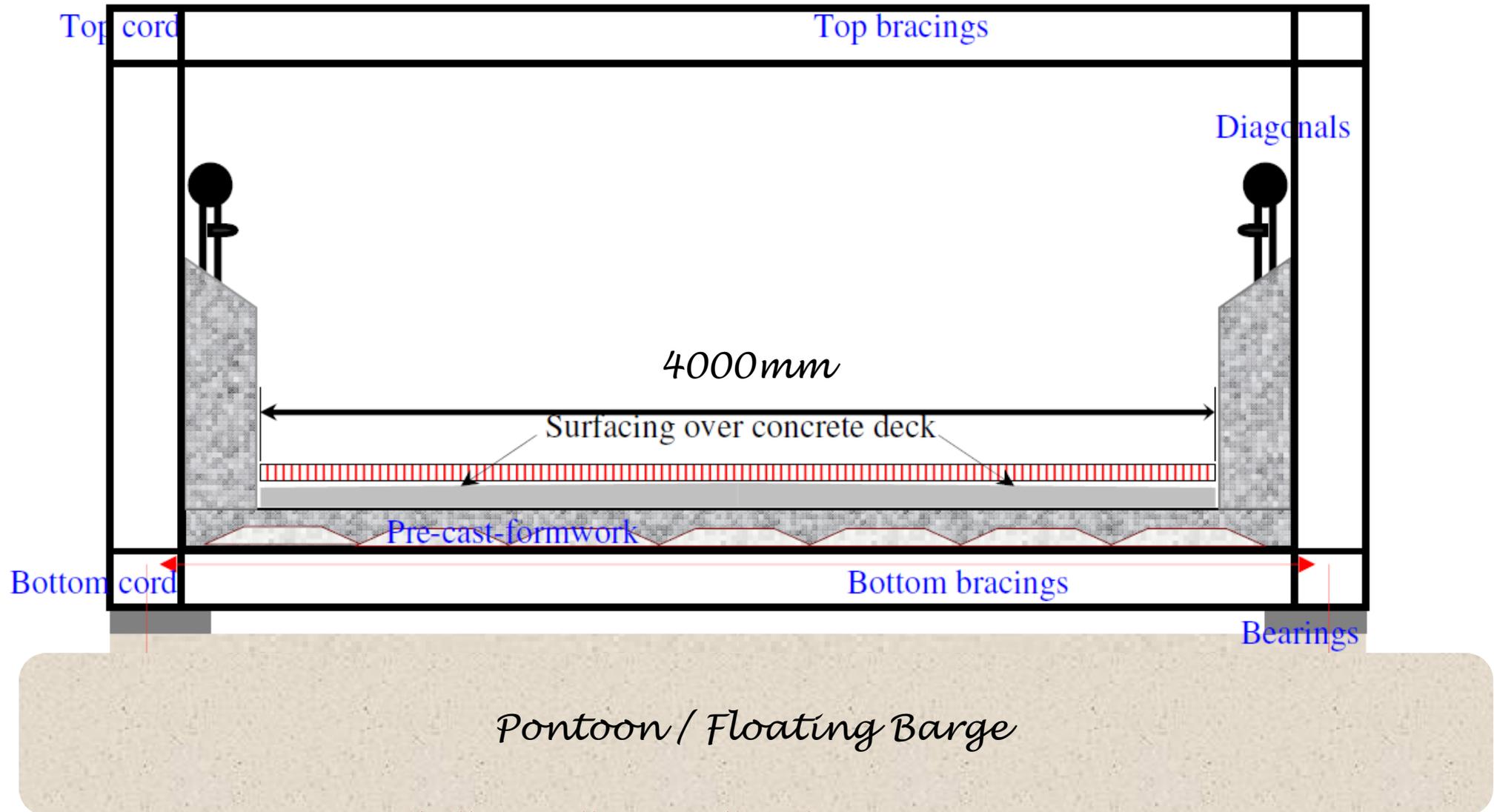


Figure 17: Typical Through truss bridge superstructure cross section

Method of Statement:

For the chosen solution, construction activity at site is negligible. Other than the construction of approach embankment there is hardly any construction activity left for this. However fabrication, transportation and erection of truss bridge superstructure especially on top of pontoon or floating barge should be highly important aspect of this method of statement. Hence the Bar chart on construction programme must be prepared with extra amount of care.